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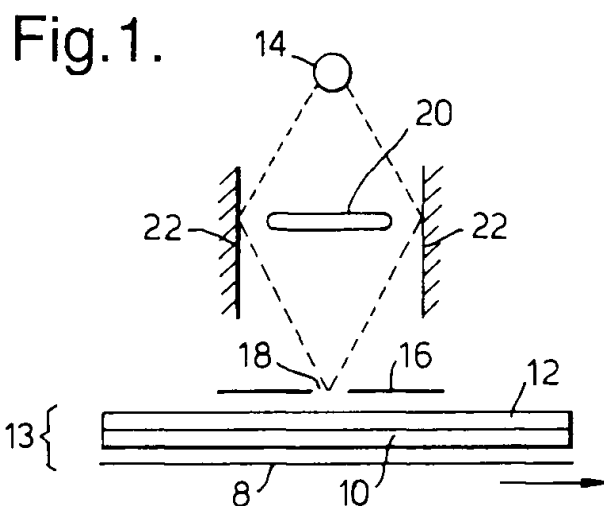
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(54) Light-diffusing screen

(57) A light diffusing screen is made by exposing a photopolymerisable material 10 to polymerising light through a mask 12 having an array of light-transmitting apertures in an opaque background or vice versa, at least some of the light being directed obliquely onto the photopolymerisable material. The resulting photopolymerised material has asymmetric light-diffusing proper-

ties. In some embodiments two beams of light directed onto the photopolymerisable material are equally and oppositely inclined to the perpendicular to the plane of the material. An analogous effect may be provided, in other embodiments, by exposing the photopolymerisable material 10 to light converging conically on the photopolymerisable material.



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Description

THIS INVENTION relates to a material suitable for use as a light diffusing screen or rear projection screen and to a material suitable for use as a front projection screen and for analogous purposes, such as in reflective signs, etc.

It is well known that the important parameters of projection screen materials include brightness, that is the amount of light, from the image source, reaching the viewer and the angles from the perpendicular to the surface of the material over which an acceptable brightness level (usually in excess of 50% of the maximum) is maintained.

In the following, reference is made to the "angle of view". In this specification, the term "angle of view" refers to the range of viewing angles of observers relative to a diffusing screen or a rear projection screen over which the apparent brightness of the screen is within 50% or more of the apparent brightness to an observer viewing the screen at right angles assuming that the light incident on the screen is incident along the normal to the screen. This figure is often referred to as "full width half maximum" or "fwhm". By way of example, the angle of view may be measured by illuminating a small area of the screen material by a laser beam (although some other collimated light beam may be used) directed normally to the plane of the screen and measuring the light diffused or reflected from that small area (according to whether a light diffusing screen - such as a back projection screen - or a reflective screen - such as a front projection screen - is involved), over a range of angles. Furthermore, in the following, the expression "angle of view for transmission" means "angle of view" defined as above for a screen of light-diffusing material illuminated by a projector or the like disposed on the opposite side of the plane of the screen from the observer, i.e. for a rear-projection screen whilst the expression "angle of view for reflection" means "angle of view" defined as above for a screen of light reflective material illuminated by a projector or the like disposed on the same side of the plane of the screen as the observer, i.e. for a front projection screen.

Established methods for producing materials suitable for front projection screens and for analogous purposes include, on the one hand, the lamination of light diffusing films to specular or "mirror like" surfaces and, on the other hand, incorporating geometric features into such surfaces, for example corner cube arrays. Where a light diffusing material is laminated to a mirror-like surface, the angle of view for reflection is approximately double the angle of view for transmission for small to moderate angles of view. With a front projection screen produced by incorporating geometric features in a reflective surface the angle of view is determined by the geometry of such features. Where a light-diffusing material is laminated to a reflective surface, increases in angle of view to achieve appropriate reflective characteristics may be impossible or may be obtainable only to the detriment of one other important factor such as brightness (reduced if film thickness is increased), flexibility or cost. Where reflective diffusion is obtained by providing an array of geometric features, the angle of view can only be changed by changing the geometric features. The geometric features can only be changed by changing the mould, press tools or other tools used to produce these features, and this is expensive.

It is among the objects of the invention to provide an improved light diffusing material suitable for use as a back projection screen, to provide an improved material suitable for use as a front projection screen or in reflective signs or in analogous applications, and to provide improved methods of manufacturing such materials.

It is known to provide a diffusion or rear projection screen by a technique in which a layer of photopolymerisable material is exposed to a pattern of polymerising light comprising an array of spots of light (or, alternatively, an array of dark spots in a light field) to induce selective polymerisation of the material with consequent refractive index gradations throughout the material, resulting in a light dispersing or diffusing effect. Such selective photopolymerisation may be brought about, for example, by applying to one surface of a layer of photopolymerisable material supported on a substrate, an optical mask comprising an array of light-transmitting areas in opaque surround (or alternatively, a mask comprising an array of opaque areas in a transparent surround). The technique may be substantially that disclosed in European Patent No. 0294122 in which the mask apertures are substantially circular, resulting in the production of an array of graded refractive index lenses in the photopolymerised layer. Alternatively, the mask apertures may be oval or ellipsoidal in shape, with their major axes extending parallel with one another, thereby producing an array of astigmatic graded refractive index lenses, as a result of which the photopolymer layer has asymmetric characteristics as regards angle of view. Techniques disclosed in co-pending International Patent Application No. PCT/GB94/01281 allow the production of a mask in which the array of apertures in the mask conforms to a random "speckle" pattern, in which individual apertures are irregularly and randomly shaped.

In the techniques described above, the polymerising light is incident on the mask and underlying photopolymer layer substantially normally. However, the applicants have discovered that useful properties can be imparted to the resulting screen if, during exposure, the light or other polymerising radiation is directed into the photopolymerisable material at an angle other than substantially normally, or if multiple sources of light or other polymerising radiation are used to create multiple beams at least some of which are inclined to the plane of the photopolymer layer. The applicants have also found that by adopting such expedients whilst at the same time ensuring that the exposure arrangement is symmetrical about a preferred axis, for example an axis normal to the layer of polymerisable material, symmetry of the resulting diffusion characteristics about such axis can be obtained. Such symmetry can also be obtained by rotation

of the assembly including the layer of polymerisable material relative to the exposure means about such axis during exposure.

According to one aspect of the invention there is provided a method of making a light-diffusing screen comprising providing a sheet of a light-transmitting radiation polymerisable (as herein defined) material of a type in which, after polymerisation, the refractive index varies with degree of polymerisation, exposing said material to a predetermined pattern of polymerising radiation comprising an array of spots of light intensity radiation in a background of lower or zero intensity radiation, or comprising an array of spots of lower or zero intensity radiation in a background of high intensity radiation, at least some of said radiation being directed along an axis which is inclined with respect to the plane of said sheet of material.

According to another aspect of the invention there is provided a light-diffusing sheet material having at least some graded refractive index features having axes or preferred orientations aligned along a direction having a component parallel with the plane of the material.

Preferably said graded refractive index features comprise a first set of graded refractive index lenses having their optical axes extending along a first direction which is inclined with respect to the plane of the screen and a second set of graded refractive index lenses having their optical axes extending along a second direction which is inclined with respect to the plane of the screen.

Whilst, in some embodiments of the invention, the polymerisable material used is such that polymerisation can be effected or initiated by exposure to light, and in particular to ultraviolet light, it will be appreciated that polymerisable material may be used which is such that polymerisation can be effected by forms of radiation, for example by electron beams or ion beams. The term "radiation polymerisable" as used herein is intended to include such variants as well as materials polymerisable by ultraviolet light.

Preferably, during the exposure of said material, it is exposed at least principally to polymerising radiation from two directions which are equally and oppositely inclined with respect to a plane which is perpendicular to the plane of the sheet of material.

However, in some embodiments of the invention, the material is exposed to radiation from a single direction inclined with respect to the plane of the material.

Diffusion or rear projection screens in accordance with some embodiments of the invention can be made to have a pronounced asymmetry. Further, by variation of such factors as the incident angles of the light used for exposure of the photopolymer, it is possible to tailor the degree of asymmetry as well as other parameters, such as "strength" of diffusion (e.g. fwhm).

Embodiments of the invention are described below with reference to the accompanying drawings, wherein:

FIGURE 1 is a diagrammatic side elevation drawing illustrating a first method of producing a diffusion screen in accordance with the present invention,

FIGURE 2 is a diagrammatic side elevation drawing illustrating a second method of producing a diffusion screen in accordance with the present invention, and

FIGURE 3 is a diagrammatic view, corresponding to Figure 2 but to a larger scale and illustrated by ray-tracing,

FIGURE 4 shows a ray trace analysis for a prismatic film,

FIGURE 5 is a view similar to Figure 1 but illustrating a further method of producing a diffusion screen in accordance with the invention,

FIGURE 6 is a view similar to Figures 1 and 5 but illustrating a yet further method of producing a diffusion screen in accordance with the invention,

FIGURE 7 is a view similar to Figure 2 but illustrating a still further method of producing a diffusion screen in accordance with the invention,

FIGURE 8 is a diagrammatic perspective view illustrating a still further method of producing a diffusion screen in accordance with the invention.

Referring to Figure 1, there is shown at 10 a layer of a transparent photopolymerisable medium supported by a flat transparent substrate 8. The medium forming layer 10 may be a photopolymerisable monomer of the kind referred to in E-0294122 EP or may be that supplied by DuPont under the Registered Trade Mark OMNIDEX and having the type designation HRF 150 or HRF 600, discussed in more detail in, for example, W095/06867. Superimposed upon

the photopolymerisable layer 10 is an optical mask 12 of any of the kinds referred to above with the apertured opaque layer on the mask being in contact with the layer 10. Means (not shown) is provided for moving the substrate (8)/mask (12)/photopolymer (10) combination (herein referred to as combination 13) in its own plane in the direction indicated by the arrow, past exposure means comprising a source 14 of polymerising radiation, such as an ultraviolet strip lamp, disposed at some distance above the plane of the combination 13 and parallel therewith, the strip lamp extending perpendicular to the direction of the arrow.

Disposed directly above the combination 13 is an opaque screen 16 spaced slightly from the mask 12 and parallel therewith, the screen 16 having an aperture or slot 18 therein which is elongate in the same direction as the strip light source 14, the slot 18 being disposed directly below source 14 so that a notional plane including the axis of the strip source 14 and that of the slot 18 is perpendicular to the plane of combination 13. An opaque baffle 20 is disposed between the source 14 and slot 18 to prevent light from the source 14 from passing directly to the slot. On either side of the baffle 20 are arranged opposing mirrors 22, parallel with one another and with the axes of strip source 14 and slot 18 and perpendicular to the plane of the layer 10.

With this arrangement, the two mirrors reflect respective beams of light from the source 14 through the slot 18 and thus through the mask 12 and into the layer 10, the two beams being equally and oppositely inclined with respect to the plane, perpendicular to the plane of combination 13, passing through the slot 18 and source 14. During such exposure, the combination 13 is traversed steadily past the slot 18 to expose the entire area of the mask (and the polymerisable medium 10 beneath the light transmitting portions of the mask). The use of a slot 18 past which the combination 13 is traversed is necessary simply to ensure that all parts of the combination are exposed to light from the same angles or the same limited range of angles. It would, of course, be possible to dispense with the traversing of the combination 13 relative to the exposure means if parallel beams of sufficient width and intensity to encompass the whole of layer 10 at once were available, but this implies, for example, the availability of relatively expensive optics. It has been found, incidentally, that it is not necessary to have a single source 14. Corresponding results have been obtained by using two separate UV light sources (such as two parallel strip sources), arranged at equal and opposite angles with respect to the slot 18.

A diffusing screen produced by the method described above with respect to Figure 1 has asymmetrical diffusion characteristics, in the sense noted above and it should be noted that the maximum spread of light by the resulting screen is greatest in planes parallel with the planes of mirrors 22 in the specific arrangement shown. The extent of such maximum spread increases with increased inclination of the beams passing through slot 18 to the normal to the plane of the photopolymer sheet 10.

It has been found that the asymmetrical diffusion effect noted is obtained even if only an initial part of the exposure of layer 10 through mask 12 is by mutually inclined light beams, with the remainder of the exposure being by radiation incident normally on the mask 12/layer 10 combination.

It will be appreciated that asymmetry of diffusion is not dependent upon strict equality of inclination of the beams used for exposure of the layer 10. Indeed, as discussed below, asymmetrical diffusion characteristics are also obtainable using an exposure regime such as shown in Figure 5 in which only a single inclined beam is used.

Referring to Figures 2 and 3, in another method of exposing the photopolymerisable layer 10 to light from two oppositely inclined directions, use is made of a transparent prismatic film or sheet 26 having a series of identical parallel roof-shaped ridges 28 forming one surface of the film or sheet 26 and having an opposing flat surface. Such a film is known, and is available from the 3M Company. Such a film is referred to as "brightness enhancing film" or "BEF", below.

In the following, referring to Figure 2, in which like parts have like references, a sheet of the prismatic film or BEF referred to is placed directly on top of the mask 12, itself, of course, placed directly on the upper surface of the layer 10 of photopolymerisable material. The prismatic film 26 is placed with its flat surface lowermost in Figure 2, engaging the mask 12. In this arrangement, the photopolymer 10 is exposed, through the film 26 and mask 12, by polymerising radiation incident on the assembly normally, (i.e. perpendicular to the plane of the layer 10, etc.), from a suitable UV light source (not shown). Unless a parallel beam of polymerising radiation of the width sufficient for exposure of the whole of the photopolymer layer 10 is available, it may, again, be necessary to expose the photopolymer through a slot disposed above the layer 10/mask 12/film 26 combination with that combination being traversed steadily beneath the slot during exposure, in much the same way as described with reference to Figure 1.

The effect of the prismatic film is illustrated in more detail in Figure 3 and is, as illustrated, to produce, below each prismatic ridge, a region in which the photopolymer is exposed to light from two directions inclined equally and oppositely with respect to the normal to the plane of the layer 10. As a result, each such region exhibits asymmetrical diffusion characteristics in much the same way as the product obtained by the method to which Figure 1 relates. Because, as illustrated in Figure 3, there are regions adjoining each trough in the prismatic film which receive light from only one (inclined) direction, these regions may not possess asymmetrical diffusion characteristics. If the pitch of the prismatic ribs (i.e. the distance between the ridge of one roof-shaped rib and the ridge of the next) is small (see Table 1 below), there is no discernible variation in diffusion characteristics from one part of the resulting photopolymer diffusion screen to another, in normal use of the screen.

Figure 4 shows a ray trace analysis for a generic prismatic film. The variables of note, assuming that the incident radiation is normal to the plane of the flat surface of the prismatic film, are the prism angle (P) and refractive index (n) of the medium. Analysis of the situation illustrated in Figure 4 shows that the exit angle α , is given by:-

$$\alpha = \sin^{-1} \left[n \cos \left(\frac{P}{2} + i \right) \right]$$

The refractive index of the photopolymerisable materials referred to above is relatively close to that of the currently preferred BEF film, namely polycarbonate, so that with the prismatic film in intimate contact with the layer 10 of photopolymerisable material, the refraction at the interface between the photopolymerisable material and the prismatic film is far less pronounced than that represented in Figure 4.

The choice of exit angles provides one means of controlling the asymmetry of the resulting product.

An example of the production of an asymmetric diffusing material by the method outlined above is set out below.

EXAMPLE 1

The photopolymerisable material used was black backed 90 μ m DuPont HRF 600 material exposed to UV light, through a mask, through polycarbonate BEF film having a prism pitch of 31 μ m, a prism angle of 100° and a refractive index of 1.586. The exposure was to UV2 ultraviolet light with an intensity of 4 mw per cm² for 15 minutes. After exposure, the polymerisable material was heated to 140°C and maintained at that temperature for 5 minutes. The following table, Table 1, illustrates the results obtained. For comparison, a diffusion screen produced using the same photopolymerisable material and mask but with normally incident radiation (i.e. without the BEF film) was also tested and the results are also set out in Table 1 below for comparison (Microsharp standard). Table 1 below also sets out corresponding results for a product obtained by laminating two layers of the photopolymer diffusion screen produced by the method described above (with the direction of widest angle view being the same for both sheets in the laminate) (Double Microsharp - BEF).

TABLE 1

Sample	FWHM-x	FWHM-y	Asymmetry Factor	Screen Gain
Microsharp - std	45°	45°	1	1.75
Microsharp - BEF	35°	13°	2.7	6.75
Double Microsharp BEF	47°	20°	2.35	2.5

As noted from the Table above, a marked degree of asymmetry in diffusion is obtainable.

As shown in Table 1 above, the screen gain (i.e. the ratio of the maximum brightness of the screen (when back-illuminated by a uniform parallel beam) as viewed at the appropriate angle to the average brightness of the screen over all viewing angles, was also increased.

Referring to Figure 5, this shows a further variant method in which the mask/polymerisable material/substrate combination 13 is illuminated by a single beam directed at an angle θ_1 relative to the normal to the plane of the mask/polymerisable material/substrate combination. The beam may simply be a slightly divergent beam coming from, e.g. an ultraviolet source, the mask/polymerisable material/substrate combination being shielded from direct radiation from the source by a baffle, as in the embodiment of Figure 1, and as in the arrangement of Figure 1 may be exposed through a slot in an opaque screen whilst the combination 13 is traversed past this slot. However, as illustrated in Figure 2, the mask/polymerisable material/substrate combination may be exposed by a collimated, i.e. substantially parallel beam, initially directed normal to the plane of the polymerisable material and reflected by an inclined mirror onto the mask/polymerisable material/substrate combination at the angle θ_1 relative to the normal, the baffle again serving to intercept direct radiation not reflected from the mirror.

It will be appreciated, of course, that it is equally possible to utilise a collimated light source directed onto the mask/polymerisable material/substrate combination without any intervening mirrors or baffles.

Figure 6 illustrates a variant of the method of claim 1, in effect, where a substantially parallel, collimated beam is directed, initially normally to the plane of the mask/polymerisable material/substrate combination 13, to be reflected by two inclined plane mirrors on either side of the material to strike the combination 13 at angles of θ_1 and θ_2 respectively

to the normal to said plane. A baffle 20 is again provided to intercept direct light not reflected from the mirrors. Again, it will be understood that the light beams striking the material at the angles θ_1 and θ_2 could alternatively come directly from respective collimated light sources arranged at the appropriate angles, without the need for respective mirrors or baffles.

Figure 7 illustrates a variant of the method of Figure 2 which, instead of the BEF being in contact with the mask 12, it is spaced thereabove by a gap (of 20 mm in the example illustrated).

Tables 2 and 3 below relate to a further set of examples, in which the exposure regime was as illustrated in Figure 5 (for examples #1 to #3); Figure 6 (for examples #4 and #5) and Figure 7 (for examples #6 and #7).

In these examples, the photopolymerisable material (90 μ m thick, clear backed DuPont HRF600 photopolymer) was exposed successively to ultraviolet light as the polymerising radiation, the light being collimated to afford a uniform parallel beam. The respective exposure energies in the UV1, UV2 and UV3 bands of the ultraviolet spectrum were as indicated in the columns headed UV1, UV2 and UV3 in Table 2 below. After exposure, the material was oven cured for 20 minutes at 100°C. The columns headed θ_1 and θ_2 in Table 2 indicate the values of θ_1 (and θ_2 where applicable) in the exposure arrangements illustrated in Figures 5 and 6.

Table 3 below sets out the light diffusing properties of the resulting products. The light diffusing properties of the material were investigated using a collimated parallel beam of light directed onto the respective material along an axis and measuring the light intensity of the light, from said beam, directed by the material at different angles relative to said axis. For some of these measurements, the angle of the plane of the material relative to said axis was varied, and the angles referred to in the column headed "Comments" in Table 3 are the angles, for these measurements, of the normal to the plane of the material to said axis. The control sample (#1) possessed a diffusion pattern exhibiting rotational symmetry about an axis normal to the plane of the material. The off-axis sample (#2) possessed a similar diffusion pattern when illuminated off-axis at an incident angle approximately equal to the recording angle of incidence such that the incident beam from the light source was aligned along the direction, relative to the material, of the beam of light used during exposure. The samples produced by the twin mirror (#4 and #5) and BEF approaches (#6 and #7) using identical processing conditions possessed very similar performance characteristics. Like the off-axis sample (#2) when illuminated at an incident angle approximately equal to either recording angle of incidence such that the incident beam from the light source was aligned along the direction, relative to the material of the beam of light used during exposure, a rotationally symmetrical diffusion pattern was observed, i.e. possessing rotational symmetry about the axis of the beam incident upon the material in the measuring set-up.

In Table 3, the columns headed "FWHM(0) x, y" relate to measurements made with the material perpendicular to the axis of the incident mean, with the plane in which the goniometer measurements were made being parallel with (y) and perpendicular to (x) the plane in which the angles θ_1 , θ_2 are measured in the regimes of Figures 5, 6 and 7 and the corresponding plane in the regime of Figures 3 and 4).

As will be noted the materials of Examples #2 to #7 possessed marked asymmetry in diffusion characteristics between the "x" and "y" measurements, this being quantified in the column headed "Asy". Thus, the asymmetric samples produced by the two mirror (#3) and BEF approaches (#6 and #7) using identical processing conditions possessed very similar performance characteristics. When illuminated by collimated light normal to their input face they possessed an approximately 2:1 elliptical profile.

The last column sets out the screen gain for each of these examples.

TABLE 2 - Summary of processing conditions

#	Description	Inc' θ_1	Inc' θ_2	UV1 mJ/cm ²	UV2 mJ/cm ²	UV3 mJ/cm ²	Oven Cure
1	Control	0°	0°	23.8	122.4	34.0	100°C for 20 mins
2	Off-axis, mirrors tilted 15°	30°	n/a	15.9	81.0	22.4	100°C for 20 mins
3	Off-axis, mirrors tilted 5°	10°	n/a	15.9	81.0	22.4	100°C for 20 mins
4	Asymmetry through twin mirrors tilted at 15°	30°	30°	31.5	162.0	44.8	100°C for 20 mins
5	Asymmetry through twin mirrors tilted at 5°	10°	10°	31.5	162.0	44.8	100°C for 20 mins
6	Asymmetry through BEF on mask	30°	30°	23.8	100.8	34.0	100°C for 20 mins
7	Asymmetry through BEF at 20mm above mask	30°	30°	23.8	100.8	34.0	100°C for 20 mins

TABLE 3: Summary of processing conditions, FWHM(0) refers the value at normal incidence

#	Description	Comments	FWHM(0) x	FWHM(0) y	Asy'	Gain
1	Control	Standard symmetrical diffuser	45°	45°	1	3.2
2	Off-axis, mirrors tilted 15°	Maximum diffusion occurs at 30°	20°	6°	3.3	30
3	Off-axis, mirrors tilted 5°	Maximum diffusion occurs at 10°	36°	20°	1.8	5.8
4	Asymmetry through twin mirrors tilted at 15°	Maximum diffusion occurs at ± 30°	33°	14°	2.4	5.9
5	Asymmetry through twin mirrors tilted at 5°	Maximum diffusion occurs at ± 10°	42°	38°	1.1	3.5
6	Asymmetry through BEF on mask	Maximum diffusion occurs at ± 30°	30°	11°	2.7	12.4
7	Asymmetry through BEF at 20mm above mask	Maximum diffusion occurs at ± 10°	32°	12°	2.7	10

Example #7 illustrates that it is not necessary to have the BEF in intimate contact with the contact mask making

the regime compatible with a continuous process.

Examples #3 and #5 also indicate how by carefully tailoring the recording geometry varying degrees of off-axis or asymmetric performance can be encoded. For example, a reduction in the mirror tilt angle will result in a reduction in the degree of asymmetry and potential off-axis performance.

Referring to Figure 8, a yet further exposure method is illustrated which is similar in some respects to the arrangement of Figure 1, except that the two opposing plane mirrors are replaced by a cylindrical mirror, that is to say by a mirror in the form of an open-ended hollow cylinder providing an internal reflective surface, the mirror being arranged above the mask/polymerisable material/substrate combination with its longitudinal axis normal to the plane of that combination, a point light source (or pseudo point light source such as a round bulb) being disposed above the upper end of the cylinder on said axis. A centrally located circular baffle is mounted with the cylinder. As a result of the circular symmetry of the arrangement about the cylinder axis, the mask/polymerisable material/substrate combination is subjected to radiation from, in effect, an extended annular light source centred on the axis of the cylinder. It will be understood that the cylindrical mirror/point light source arrangement may in fact be replaced by a real extended annular light source. A similar effect may be provided by, for example, providing a single collimated beam striking the mask/polymerisable material/substrate combination at a desired angle to the normal and rotating the combination in its own plane at a speed sufficient to ensure that the period of one revolution is small in relation to the curing time or the polymerisation initiation time of the material.

As a further variation (not illustrated) of the method of Figure 1, and by analogy with Figure 6, the combination 13 may be exposed using a collimated parallel beam of polymerising radiation directed initially normally towards the combination but reflected onto the combination 13 by a hollow frusto-conical mirror.

Whilst in the examples described with reference to Figures 1 to 4 and 6 to 8, the exposure arrangement is symmetrical about an axis or plane perpendicular to the plane of the polymerisable material, for some applications, for example where, in use, the diffusing material will be illuminated obliquely, the exposure arrangement may be centred on an axis or plane which is inclined to the plane of the polymerisable material. Thus, for example, in an arrangement similar to that of Figure 6, the mirrors may not be equally inclined so that consequently the angles θ_1 and θ_2 may be different. Likewise, in an arrangement similar to that of Figure 8, the axis of the cylindrical mirror may be inclined relative to the plane of the polymerisable material, or the light source may be offset laterally from the axes of the cylinder.

Similarly, in arrangements using prismatic film, such as those illustrated in Figures 2 to 4 and 7, the light may be incident obliquely on the prismatic film/mask/polymerisable material sandwich so as to be inclined at different angles to the two faces of each prism. Alternatively, or additionally, the individual prisms of the prismatic film may be asymmetrical, for example of saw-tooth form.

As indicated above, it is preferred, in most applications, that the light diffusing material should be uniform as to its light diffusing properties over the whole area of the material and this may be achieved by using, for exposure, collimated parallel beams of light or other polymerising radiation which are of sufficient width and which are sufficiently uniform across their width, where the material is exposed through a contact mask. Alternatively, the material may be traversed past a slot, as in Figure 1, during exposure, to secure uniformity over an extended length of the material. However, as also indicated above, for some applications lack of uniformity across the area of the material may not present any disadvantage and, indeed, may be deliberately induced to secure a particular effect. It is contemplated, for example, that it may be possible, by using polymerising radiation striking the material at different angles in different zones to produce diffusion screens which also operate to some degree as lenses or prisms, perhaps using a stepped variation in exposure angle to provide structures analogous to Fresnel lenses or prisms.

Whilst, in the examples illustrated with reference to the drawings, selective exposure of the polymerisable material to polymerising radiation is obtained by "contact printing", i.e. by exposure through an aperture mask in contact with the material, it will be understood that such selective exposure may also be obtained in other ways, for example by an image projection arrangement, by an intermittently energised scanned beam, or even holographically using coherent light.

It will be understood that whereas, for most applications, collimated (parallel) beams are preferred for exposure, diverging or converging beams may be used in some instances. Likewise, mirrors may be used which are convex or concave, rather than plane, depending upon the effects desired.

The features disclosed in the foregoing description, in the following claims and/or in the accompanying drawings may, both separately and in any combination thereof, be material for realising the invention in diverse forms thereof.

Claims

1. A method of making a light-diffusing screen comprising providing a sheet of a light-transmitting radiation polymerisable (as herein defined) material of a type in which, after polymerisation, the refractive index varies with degree of polymerisation, exposing said material to a predetermined pattern of polymerising radiation comprising an array

of spots of light intensity radiation in a background of lower or zero intensity radiation, or comprising an array of spots of lower or zero intensity radiation in a background of high intensity radiation, at least some of said radiation being directed along an axis which is inclined with respect to the plane of said sheet of material

- 5 2. A method according to claim 1 wherein, during the exposure of said material, it is exposed at least principally to polymerising radiation from two directions which are oppositely inclined with respect to a plane which is perpendicular to the plane of the sheet of material.
- 10 3. A method according to claim 2 wherein the illumination from two sides is obtained by using two mirrors to reflect light from a common source onto the photopolymerisable material.
- 15 4. A method according to claim 3 wherein the illumination from two sides is obtained by superimposing upon the photopolymerisable material a sheet of light-transmitting material having a series of parallel, gable-shaped ridges, and directing a beam of polymerising light onto the prismatic material.
- 20 5. A method according to any of claims 2, 3 or 4 wherein said two directions are at different angles with respect to said plane perpendicular to the plane of said material.
6. A method according to any of claims 2, 3 or 4 wherein said two directions are equally and oppositely inclined with respect to said plane perpendicular to the plane of said material.
- 25 7. A method according to claim 1 wherein during exposure of said material, it is exposed to radiation from three or more directions.
8. A method according to claim 1 wherein during exposure of said material, it is exposed to radiation from a real or virtual annular region centred on an axis perpendicularly to the plane of the material.
- 30 9. A method according to claim 8 wherein the material is exposed to polymerising radiation using a mirror in the form of a hollow open-ended body of rotation having an internal reflective surface, said material being disposed on the axis of said body at or adjacent one end of the cylindrical mirror and a source of said polymerising radiation being placed on said axis at or adjacent the opposite end of the cylindrical mirror so that radiation from said source can enter said body of rotation to be reflected from the wall thereof onto said material.
- 35 10. A method according to claim 9 wherein said body of rotation is a cylinder.
11. A method according to claim 9 wherein said body of rotation is a frustum of a cone.
- 40 12. A method according to any of claims 9 to 11 wherein a stop is provided to prevent or limit light reaching said material directly from said source.
- 45 13. A method according to claim 1 wherein, during exposure of said material it is exposed to polymerising radiation from a direction inclined to the plane of the material whilst the material is rotated in its own plane, or whilst the source of said radiation is rotated around the material about an axis normal to the plane of said material.
- 50 14. A light-diffusing sheet material having at least some graded refractive index features having axes or preferred orientations aligned along a direction having a component parallel with the plane of the material.
15. A material according to claim 14, wherein said graded refractive index features comprise graded refractive index lenses having their optical axes extending along a direction which is inclined with respect to the plane of the material.
- 55 16. A material according to claim 15 wherein said graded refractive index features comprise a first set of graded refractive index lenses having their optical axes extending along a first direction which is inclined with respect to the plane of the material and a second set of graded refractive index lenses having their optical axes extending along a second direction which is inclined with respect to the plane of the material whereby the material has asymmetrical diffusion characteristics, as herein defined.
17. A material according to claim 16 wherein said first direction and said second direction lie in a common plane

perpendicular to the plane of said screen and are oppositely inclined to the normal to the plane of said screen.

18. A material according to any of the claims 14 to 17 which comprises a photopolymer.

5 19. A light diffusing material according to claim 14 wherein the mean orientational direction of said graded refractive index features is perpendicular to the plane of said material.

20. A screen of light diffusing material according to claim 14 wherein the mean orientational direction of said graded refractive index features is itself inclined with respect to the plane of the material.

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Fig.1.

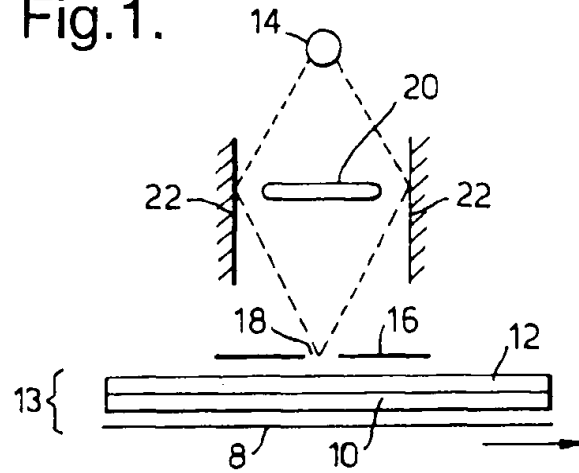


Fig.2.

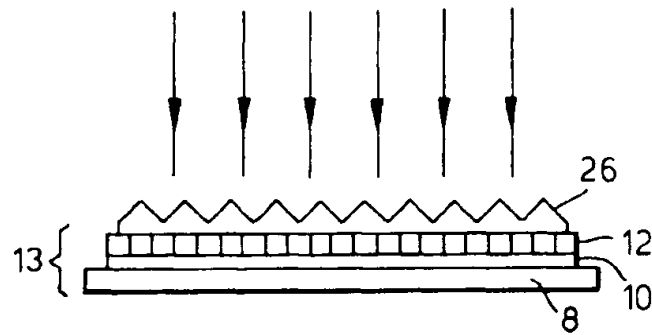


Fig.3.

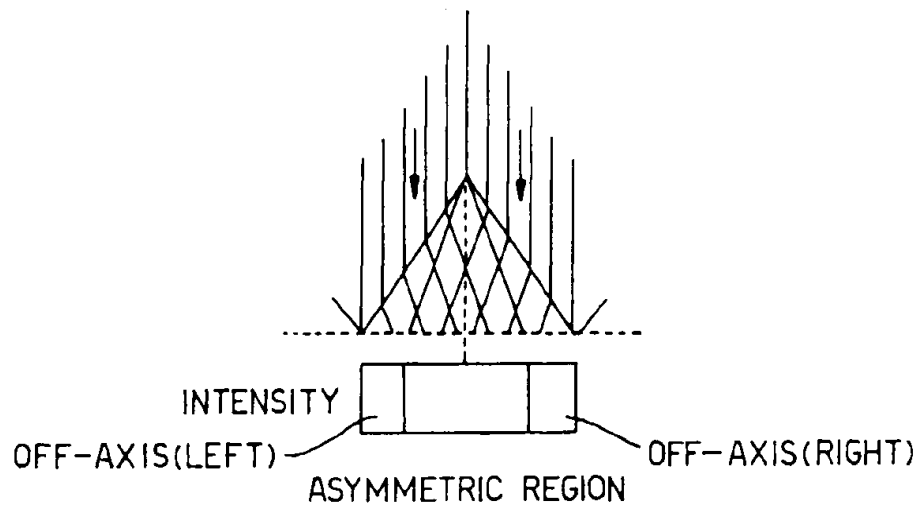


Fig.4.

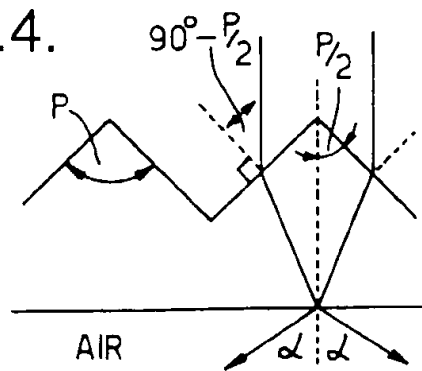


Fig.5.

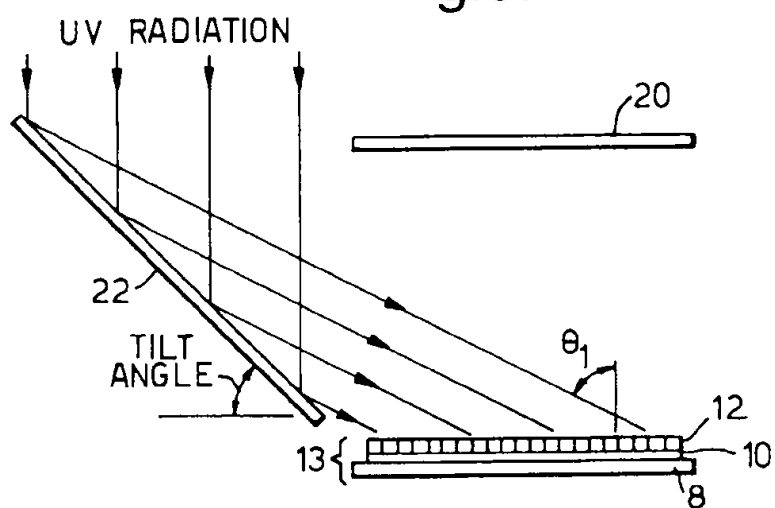


Fig.6.

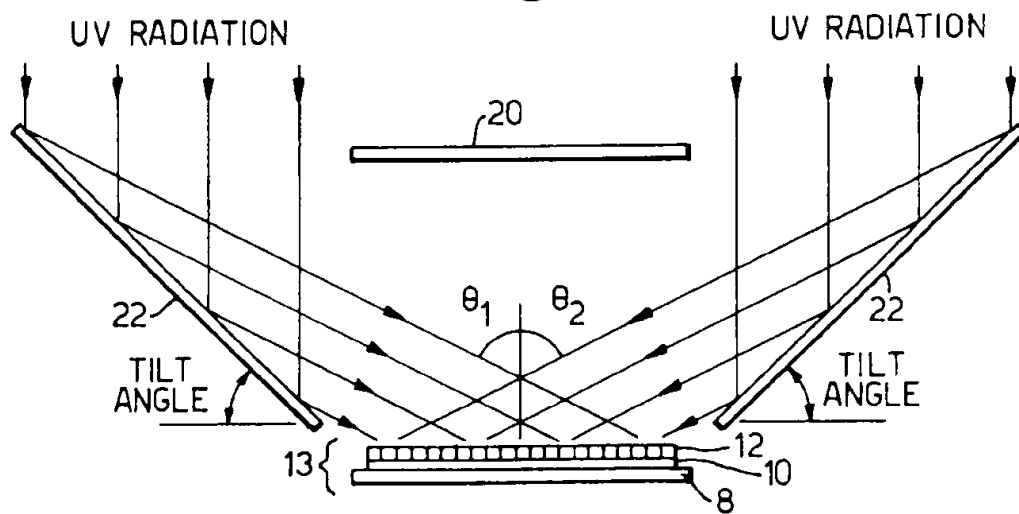


Fig.7.

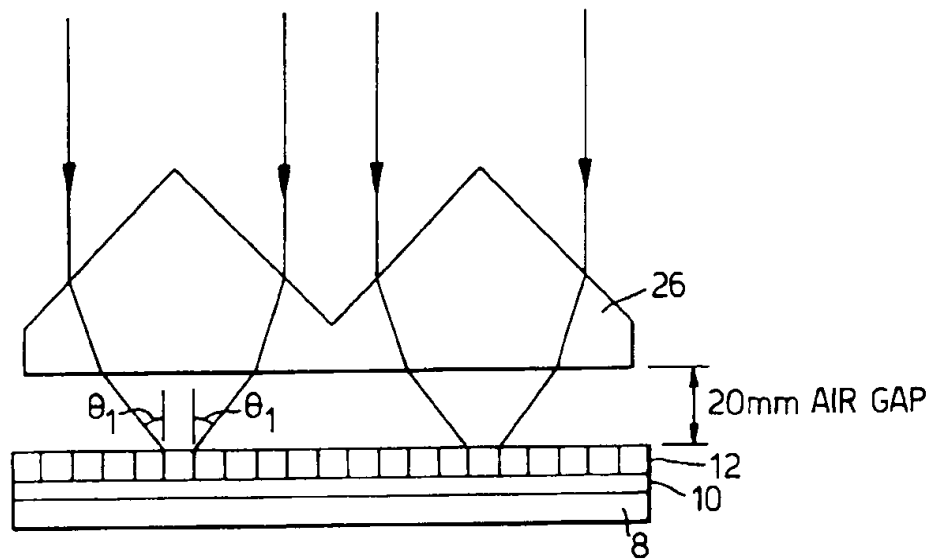


Fig.8.

